doi: 10.1002/osp4.358

ORIGINAL ARTICLE

Edmonton Obesity Staging System for Pediatrics, quality of life and fitness in adolescents with obesity

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Received 8 February 2019; revised 3 July 2019; accepted 5 July 2019

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Clinical trial registration number and date: ClinicalTrials. Gov NCT00195858, 12 September 2005

Summary

Background

Body mass index (BMI) is often used to diagnose obesity in childhood and adolescence but has limitations as an index of obesity-related morbidity. The Edmonton Obesity Staging System for Pediatrics (EOSS-P) is a clinical staging system that uses weight-related comorbidities to determine health risk in paediatric populations. The purpose of this study was to investigate the associations of EOSS-P and BMI percentile with quality of life (QOL), cardiorespiratory fitness (CRF) and muscular strength in adolescents with obesity.

Methods

Participants were enrolled at baseline in the Healthy Eating, Aerobic and Resistance Training in Youth trial (BMI = 34.6 ± 4.5 kg m^{-2}, age = 15.6 ± 1.4 years, N = 299). QOL, CRF (peak oxygen uptake, VO_{2peak}) and muscular strength were assessed by the Pediatric QOL Inventory (PedsQL), indirect calorimetry during a maximal treadmill test and eight-repetition maximum bench and leg press tests, respectively. Participants were staged from 0 to 3 (absent to severe health risk) according to EOSS-P. Associations were assessed using age-adjusted and sex-adjusted general linear models.

Results

Quality of life decreased with increasing EOSS-P stages ($p < 0.001$). QOL was 75.7 ± 11.4 in stage 0/1, 69.1 ± 13.1 in stage 2 and 55.4 ± 13.0 in stage 3. BMI percentile was associated with VO_{2peak} ($\beta = -0.044$ mlO_2 kg^{-1} min^{-1} per unit increase in BMI percentile, $p < 0.001$), bench press ($\beta = 0.832$ kg per unit increase in BMI percentile, $p = 0.029$) and leg press ($\beta = 3.992$ kg, $p = 0.003$). There were no significant differences in treadmill time or VO_{2peak} between EOSS-P stages ($p > 0.05$).

Conclusion

As EOSS-P stages increase, QOL decreases. BMI percentile was negatively associated with CRF and positively associated with muscular strength.

Keywords: assessment, EOSS, overweight, teenager.

Introduction

Body mass index (BMI) percentile is currently the most commonly used measure to diagnose obesity in adolescents. BMI is calculated by dividing weight by height squared (kg m^{-2}). Children or adolescents aged 2 to 19 with BMI in the 85th to 94th percentile for their age and sex are classified as overweight, while with BMI ≥95th percentile, they would be classified as having obesity (https://www.cdc.gov/growthcharts/). Although BMI or BMI percentile is practical and inexpensive, in recent years, it has been heavily criticized due to its overly simplistic approach to determining severity and biopsychosocial impacts of obesity (1,2), its limitations in paediatric populations (3) and its potential to misdiagnose overweight or obesity (4–7). Two adolescents with

the same BMI or BMI percentile can have very different body compositions and health status. In fact, some adolescents with elevated BMI may be metabolically healthy (8,9). The classification of obesity by BMI or BMI percentile does not provide information on how excess adiposity may negatively impair health and well-being of an adolescent. Adolescents with obesity may experience weight-related comorbidities, which occur when excess adiposity negatively affects an individual's metabolic, mental, biomechanical and/or social health and well-being. Examples of comorbidities include but are not limited to cardiovascular disease, type 2 diabetes, obstructive sleep apnoea, anxiety and depression (10) that can ultimately lead to decreased fitness and quality of life (QOL) (11). Better assessment tools are needed in obesity (12), and having access to a clinical staging system of obesity that allows healthcare professionals to better determine the health and well-being of adolescents with obesity is necessary for guiding clinical care.

Created in 2016, the Edmonton Obesity Staging System for Pediatrics (EOSS-P) is the first assessment tool created to classify paediatric obesity by weight-related comorbidities and weight-management barriers. EOSS-P takes into account the patient's metabolic health, mental health, biomechanical health and social milieu (4Ms) to determine the severity of obesity and provide prognostic information and to help guide future clinical care. EOSS-P was not intended to replace BMI percentile but rather to complement it by improving risk stratification of paediatric obesity. EOSS-P is based on the Edmonton Obesity Staging System (EOSS) for adults and is carefully tailored for usage in paediatrics (1). The EOSS staging for adults has been shown to be a better predictor of mortality than BMI-based obesity classifications (13,14). Adults with higher EOSS stages (e.g. stages 2 and 3) require longer weight-management treatment time than adults with lower EOSS stages (e.g. stages 0 and 1) to achieve similar weight loss outcomes (15). EOSS for adults is being used as an assessment tool in bariatric clinics in Canada, Germany and Brazil (16). To date, only one study has investigated the associations of EOSS-P with BMI class in paediatrics and found as BMI class increased biomechanical health and social milieu issues increased, while metabolic and mental health were not different (17). No studies have evaluated how EOSS-P is associated with health and well-being markers in children or adolescents with obesity.

Previous studies evaluating EOSS for adults used mortality (13) and survival (14) as adverse health outcomes. However, mortality due to chronic disease in adolescents is extremely low, instead this paper focuses on markers of future morbidity and mortality. In the current study, cardiorespiratory fitness and QOL were used as surrogate measures of health and well-being. QOL, cardiorespiratory fitness and muscular strength are feasible measures known to be good representations of health and well-being in adolescents (18,19). QOL is consistently lower in populations with chronic disease (20), and promotion of QOL has been identified as an over-arching public health goal from Healthy People (United States governmental public health organization) 2000, 2010 and 2020 (21). Cardiorespiratory fitness is the capacity of an individual to carry out long, strenuous exercise (22). Cardiorespiratory fitness has been proposed by the American Heart Association for routine assessment in clinical practice because of its strong association with cardiovascular disease and all-cause mortality (23). Higher levels of cardiorespiratory fitness and physical activity are associated with significantly lower risk of mortality in individuals with obesity (24). Cardiorespiratory and muscular fitness are consistently lower in populations with chronic diseases and are independently associated with metabolic risk factors in adolescents (18,25). Muscular strength is associated with higher insulin sensitivity in adolescents (26), and higher strength is a strong predictor of lower mortality and longer life expectancy in adults (27). QOL, cardiorespiratory fitness and muscular strength may, therefore, be markers of general health and well-being, and a single assessment tool that demonstrates associations with these measures in a population of adolescents with obesity would be optimal to help healthcare professionals guide clinical care for their patients.

The purpose of this study was to investigate EOSS-P and BMI percentile regarding their associations with QOL, cardiorespiratory and muscular strength in a sample of adolescents with overweight and obesity. The hypothesis was that both EOSS-P and BMI percentile would be negatively associated with QOL, cardiorespiratory fitness and muscular strength. This is the first study investigating the relationship of EOSS-P with important paediatric health and well-being outcomes in adolescents.

Methods

Study design

This is a secondary data analysis from the Healthy Eating, Aerobic and Resistance Training in Youth (HEARTY) randomized controlled trial completed between 2005 and 2011 (28). The primary results of the HEARTY trial were that aerobic training, resistance training and combined exercise training reduced per cent body fat and waist circumference, and there were no differences in per cent body fat loss between the exercise modalities in the overall study population (29). In more adherent participants, combined training showed greater decreases in per cent body fat and waist circumference compared with the

other exercise groups (29). At baseline, participants completed a series of assessments that were used to establish EOSS-P scores. QOL, cardiorespiratory fitness and muscular strength were also assessed at baseline. This study focuses on cross-sectional data collected at baseline.

Participants

Detailed methods of the HEARTY trial have been described previously (28). Participants were recruited by advertisements in city buses, poster print advertisements, radio campaigns, word of mouth, in schools and from referrals from physicians. Baseline participants (N = 304) included were a community sample of physically inactive post-pubertal adolescents (Tanner stage 4–5 (30,31)) with overweight or obesity aged 14–18 years old in Ottawa (Ontario) and Gatineau (Quebec), Canada, who volunteered for the HEARTY trial. Participants were eligible for the study if their BMI was ≥95th percentile for their age and sex or ≥85th percentile (https://www.cdc.gov/growthcharts/) with an additional risk factor for diabetes or cardiovascular disease. Twenty-two (7%) participants had overweight, while n = 282 (93%) had obesity. The sample had a mean BMI percentile of 97.8, ranging from 87.2 to 99.8. The majority of the sample was Caucasian (72%), followed by Black (10.2%), Mixed (4.6%), Arabic (3.6%), Asian (3.3%), Hispanic (3.0%), Other (2.0%) and Native Canadian (1.3%). Informed consent was obtained from participants 16 years and older, as well as from a parent or legal guardian of participants under 16. Participants under 16 gave informed assent. All data were collected from adolescent participants (not parents or guardians). The research ethics boards at the Children's Hospital of Eastern Ontario and the Ottawa Hospital approved this study.

Edmonton Obesity Staging System for Pediatrics

Edmonton Obesity Staging System for Pediatrics categorizes obesity using a 4-point staging system ranging from stage 0 (no risk), stage 1 (mild risk), stage 2 (moderate risk) and stage 3 (severe risk). Using EOSS-P guidelines from the original EOSS-P tool development (1), a team consisting of five experts (two clinical paediatric psychologists, one paediatric endocrinologist and two obesity researchers) was consulted to create the EOSS-P algorithm applicable for assessment of HEARTY participants (Table 1). A primary evaluator (G. A. K.) staged all participants, and a secondary evaluator (M. L.) evaluated a random sample (n = 30, 10% of total sample) for interrater reliability. The interrater Cronbach's alpha was 0.959, indicating near-perfect agreement. The mental health questionnaires used in HEARTY that were specific to the EOSS-P algorithm used in this study are listed in Table 1.

Cardiorespiratory fitness

A certified exercise physiologist assessed peak oxygen uptake (VO_{2peak}) with indirect calorimetry (MOXUS Modular Metabolic System, AEI Technologies Naperville, IL, USA) during a maximal treadmill test, the gold standard for measurement of cardiorespiratory fitness (32). During the VO_{2peak} test, participants were instructed to walk on a treadmill at a progressively increasing incline following the modified Balke and Ware incremental treadmill protocol (33) until volitional fatigue. Treadmill time (i.e. the duration of the cardiorespiratory fitness test from start to finish) was also measured.

Muscular strength

An exercise specialist assessed upper body (bench press) and lower body (leg press) muscular strength using eight-repetition maximum tests (the maximum weight that could be lifted eight times for each exercise while maintaining proper form through the full range of motion).

Quality of life

HEARTY participants themselves completed the 23-item adolescent version of the Pediatrics QOL Inventory 4.0 (PedsQL) (24) as part of a larger battery of measures. The PedsQL is divided into four categories including physical functioning (eight items), emotional functioning (five items), social functioning (five items) and school functioning (five items). Each item is ranked using a 5-point Likert scale ranging from 'never' to 'almost always'. The total score was used for the analyses. The PedsQL is a reliable and feasible questionnaire that has been validated to assess QOL in a sample of adolescents with obesity (3,34). This validation study showed that PedsQL had an internal consistency alpha of 0.80 (34).

Statistical analysis

Because five participants were lacking mental health data, their EOSS-P scores could not be assessed, and these participants could not be included in the analysis. Thus, the final analysis included N = 299. There were no significant differences in BMI, age or sex of the missing n = 5 participants compared with the included sample n = 299. Baseline characteristics were compared between EOSS-P stages using ANOVA. General linear models were created to determine associations of EOSS-P and BMI percentile with QOL, cardiorespiratory fitness and

Table 1 Edmonton Obesity Staging System for Pediatrics staging criteria

Stage 1: Presence of subclinical obesity-related risk factors
Acanthosis nigricans
Pre-hypertension: systolic or diastolic
Impaired glucose tolerance (7.8–11.0 mmol L^{-1}) and/or impaired fasting glucose (6.1–6.9 mmol L^{-1})
LDL-C and/or non-HDL-C 3.4–4.1 mmol L^{-1}
HDL-C 0.8–1.03 mmol L^{-1}
Triglycerides 1.5–4.0 mmol L^{-1}
ALT 1.5–2.0× normal values
Mild depression or anxiety that does not interfere with functioning
(Diagnosis of anxiety of depression greater than 2 years ago with no current treatment) or (CDI score in 84th to 92th percentile [above average])
Mild body image preoccupation/concern
(MBSRQ Appearance Evaluation mean score 2–2.99 [neither agree nor disagree to mostly disagree])
Mild emotional/binge eating (occasional)
(1× per month to <1× per week) or (DEBQ emotional eating subscale mean score 3–4 [sometimes to often])
ADHD and/or learning disability
Caregiver has or is recovering from medical/physical, mental health and/or substance-use problems
Stage 2: Presence of obesity-related chronic diseases/health issues
Type 2 diabetes without diabetes-related complications
Hypertension: systolic or diastolic
LDL-C or non-HDL-C >4.2 mmol L^{-1}
HDL-C <0.8 mmol L^{-1}
Triglycerides >4.0 mmol L^{-1}
ALT 2–3× normal values
Polycystic ovarian syndrome
Gastroesophageal reflux disease
Major depression or anxiety disorder
(Diagnosis of anxiety of depression within 2 years ago) or (on pharmacological treatment) or (CDI score in 93rd to 97th percentile [much above average])
Moderate binge eating (frequent)
(1× to 6× per week) or (DEBQ Emotional Eating subscale 4.01 to 5 [often to always])
Significant body image disturbance
(MBSRQ Appearance Evaluation subscale mean score 1 to 1.99) or (mostly disagree to definitely disagree)
Stage 3: Presence of established chronic diseases/health issues
Type 2 diabetes with diabetes-related complications or HbA1c ≥8
Elevated lipids requiring pharmacotherapy
ALT >3× normal limits and/or liver dysfunction
Hypertension on pharmacotherapy
Uncontrolled hypertension on pharmacotherapy
Uncontrolled psychopathology
(CDI score greater than 98th percentile [very much above average])
Severe binge eating (daily)
(Binge eating 7× per week)
Self/physical loathing

The HEARTY diagnostic criteria for this specific Edmonton Obesity Staging System for Pediatrics variable in this study.
ADHD, attention deficit hyperactivity disorder; ALT, alanine transaminase; CDI, Children's Depression Inventory; DEBQ, Dutch Eating Behavior Questionnaire; HbA1c, haemoglobin A1c; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MBSRQ, Multidimensional Body–Self Relations Questionnaire.

muscular strength. Age and sex were adjusted in the analysis. Confounding variables were determined *a priori*. Differences in mean PedsQL scores across EOSS-P stages were assessed using ANOVA with post hoc tests (Bonferroni adjustment) for each successive EOSS-P stage. All analyses were conducted SPSS Statistics for

Windows, version 24 (IBM Corp., Armonk, NY, USA). Unstandardized beta estimates are presented to see the effect of each predictor (BMI percentile, EOSS-P, age and sex) on each outcome (QOL and fitness).

Results

Table 2 displays the baseline characteristics of the 299 participants included in the study. The sample included a total of 88 (29%) males and 211 (71%) females. The EOSS-P distribution of the sample in stage 0 was $n = 7$ (2%), stage 1 $n = 116$ (39%), stage 2 $n = 146$ (49%) and stage 3 $n = 30$ (10%). The mean BMI of the overall sample was 34.6 ± 0.5 kg m^{-2}, and mean BMI percentile was 97.8 ± 1.9. There were no significant baseline differences in age, BMI, BMI percentile, VO_{2peak}, treadmill time, leg press and bench press between the four EOSS-P stages except for QOL ($p < 0.001$).

Table 3 shows parameter estimates for EOSS-P, BMI percentile, sex and age for each outcome, including QOL, cardiorespiratory fitness and muscular strength. Because only 2.5% of the sample was stage 0, stages 0 and 1 were grouped together for the analysis. In all general linear models, stage 0/1 was used as the reference variable for EOSS-P, and female sex was the reference variable for sex.

Quality of life

Three participants were missing QOL assessments. For QOL as the outcome, there were significant differences between stage 0/1 and stage 2 ($p < 0.001$) and between stage 0/1 and stage 3 ($p < 0.001$). BMI percentile showed no significant association with QOL (Figure 1). The greatest differences in QOL scores were found between stage 0/1 and stage 3. Post hoc analysis revealed significant differences between stages 2 and 3 (Figure 2). Sex

Table 2 Baseline participant characteristics

	Total sample ($N = 299$)	Stage 0 ($n = 7$)	Stage 1 ($n = 116$)	Stage 2 ($n = 146$)	Stage 3 ($n = 30$)
	N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)
Male	88 (29.4)	1 (14.3)	33 (28.4)	46 (31.5)	8 (26.7)
Female	211 (70.6)	6 (85.7)	83 (71.5)	100 (68.5)	22 (73.3)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	15.6 (1.4)	15.9 (1.3)	15.6 (1.4)	15.6 (1.3)	15.8 (1.5)
BMI (kg m^{-2})	34.6 (4.5)	35.4 (6.2)	34.0 (3.9)	35.2 (4.8)	34.2 (4.1)
BMI percentile	97.8 (1.9)	97.5 (1.9)	97.8 (1.5)	97.9 (2.0)	97.6 (2.3)
PedsQL	70.4 (13.8)*	81.1 (10.1)	75.4 (11.4)	69.1 (13.1)	55.4 (13.0)
VO_{2peak} (mlO_2 kg^{-1} min^{-1})	30.4 (5.0)	31.6 (7.5)	30.7 (4.7)	30.1 (5.2)	29.8 (4.9)
VO_{2peak} treadmill time (s)	993.3 (177.5)	1,045.7 (184.2)	1,009.0 (178.1)	980.7 (180.3)	982.5 (161.0)
Bench press (kg)	22.0 (11.6)	32.7 (17.7)	28.1 (10.7)	28.1 (12.0)	26.3 (11.5)
Leg press (kg)	102.3 (37.7)	123.0 (52.9)	101.7 (34.4)	102.9 (39.1)	98.2 (41.3)

*$p < 0.001$ testing for overall group differences across Edmonton Obesity Staging System for Pediatrics stage 0/1, 2 and 3 using ANOVA.
BMI, body mass index; PedsQL, Pediatric Quality of Life Inventory; SD, standard deviation.

Table 3 Parameter estimates for each outcome

	PedsQL ($n = 296$)			VO_{2peak} (mlO_2 kg^{-1} min^{-1}) ($n = 299$)			Treadmill time (s) ($n = 299$)			Seated bench press (kg) ($n = 248$)			Leg press (kg) ($n = 248$)		
	B	Std. error	Sig.	B	Std. error	Sig.	B	Std. error	Sig.	B	Std. error	Sig.	B	Std. error	Sig.
Stage 0/1	Reference			Reference			Reference			Reference			Reference		
Stage 2	−6.85	1.52	<0.001	−0.67	0.54	0.22	−30.90	34.92	0.39	−0.84	1.31	0.52	−0.66	4.56	0.89
Stage 3	−20.14	2.51	<0.001	−1.08	0.89	0.23	−30.84	20.99	0.14	−1.49	2.13	0.49	−2.54	7.43	0.73
BMI percentile	−0.10	0.42	0.82	−1.04	0.15	<0.001	−22.61	5.79	<0.001	0.83	0.38	0.029	3.99	1.32	0.003
Female	Reference			Reference			Reference			Reference			Reference		
Male	4.52	1.70	0.008	5.28	0.60	<0.001	96.94	23.59	<0.001	12.25	1.45	<0.001	26.68	5.03	<0.001
Age (per year)	−0.89	0.52	0.09	−0.33	0.19	0.08	−10.85	7.25	0.14	1.15	0.45	0.011	5.35	1.56	0.001

Parameter estimates (B) are the change in the dependent variable associated with each unit increase of the independent variable, while all other variables are constant.
BMI, body mass index; PedsQL, Pediatric Quality of Life Inventory.

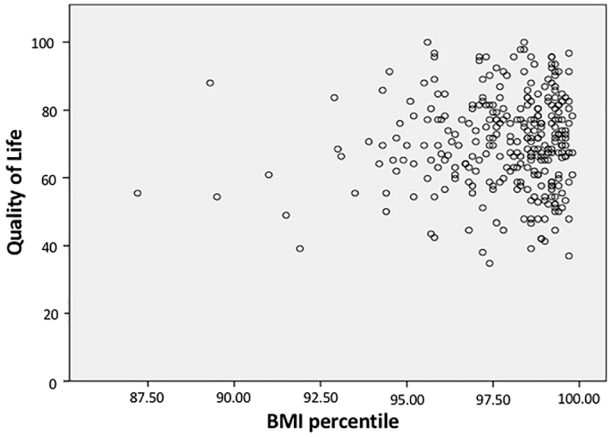

Figure 1 Quality of life across body mass index (BMI) percentiles.

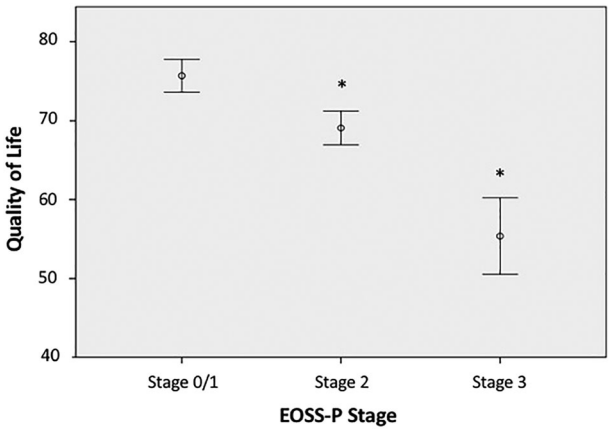

Figure 2 Quality of life at each Edmonton Obesity Staging System for Pediatrics (EOSS-P) stage. Error bars: 95% confidence interval; $^{*}p < 0.001$ when stage 2 was compared with stage 0/1, and when stage 3 was compared with both stage 2 and stage 0/1.

was associated with QOL, with males having higher QOL scores ($p = 0.008$) (Table 3).

Cardiorespiratory fitness

There were no significant differences in VO_{2peak} between EOSS-P stages ($p = 0.32$). BMI percentile was negatively associated with VO_{2peak} ($p < 0.001$), with a decrease of 1.05 mlO_2 kg^{-1} min^{-1} for each unit increase in BMI percentile.

Cardiorespiratory fitness and BMI percentile are outcome variables measured relative to a person's body weight; thus, similar models were created replacing VO_{2peak} with VO_{2peak} treadmill time (time to reach VO_{2peak}) as the outcome, to account for body weight. There were no significant differences in treadmill time between EOSS-P stages ($p = 0.31$). BMI percentile was negatively associated with treadmill time ($p < 0.001$). There were sex differences in treadmill time ($p < 0.001$), with males taking on average 97 s more time to reach VO_{2peak}. Age showed no significant association with treadmill time (Table 3).

Muscular strength

Fifty-one participants were missing muscular strength assessments. There were no associations found between EOSS-P and upper body strength ($p = 0.71$). BMI was positively associated with upper body strength ($p = 0.029$), with an increase of 0.8 kg per unit of BMI percentile. Males had significantly greater upper body strength than females ($p < 0.001$). Age was positively associated with upper body strength ($p = 0.011$).

There were no associations found between EOSS-P and lower body strength ($p = 0.94$). BMI percentile showed a positive association with lower body strength ($p = 0.003$), with an increase of 4.0 kg per unit of BMI percentile. Males had significantly greater lower body strength than females ($p < 0.001$). Age was positively associated with lower body strength ($p = 0.001$) (Table 3). Additional analyses were conducted with upper and lower body strength expressed relative to body weight, and the same trends were observed as the aforementioned results regarding the associations of BMI percentile and EOSS-P with upper and lower body strength.

Discussion

The results showed that EOSS-P was associated with QOL, but not associated with cardiorespiratory fitness or muscular strength. In contrast, BMI percentile was not associated with QOL but was negatively associated with cardiorespiratory fitness and positively associated with muscular strength. The contrasting findings between EOSS-P and BMI percentile provide insight on how they can complement each other.

The majority of the EOSS studies have been conducted in adults. Padwal *et al*. (14) found no observable differences in mortality risk between stages 0 and 1 but found elevated mortality risk in stage 2, and more so in stage 3. Kuk *et al*. (13) observed individuals with normal weight as the reference group and found stage 0/1 to have no difference in all-cause mortality, but stage 2 and stage 3 had elevated risks of all-cause mortality. Consistent with these prior studies in adults, stage 2 had lower QOL than stage 0/1, and stage 3 had lower QOL than stage 0/1 and 2.

Quality of life and all-cause mortality are associated with individual's psychological, social and physical health (13,14,20,35). Conversely, cardiorespiratory and muscular fitness are predominantly reflective of physical health

(18,23,36). Because EOSS-P is a tool that reflects 4Ms, this may explain why there was no significant association between EOSS-P and cardiorespiratory fitness or muscular strength. Although the association was not significant, participants in higher EOSS-P stages displayed lower cardiorespiratory fitness and muscular strength scores. Considering the evidence surrounding cardiorespiratory fitness and muscular strength as important markers of health (18,23,36), and the lack of significant association between EOSS-P and fitness, it is plausible that EOSS-P is lacking physical activity and/or fitness components. This study, however, treated cardiorespiratory fitness and muscular strength as baseline observations. It would be advantageous to conduct follow-up longitudinal studies utilizing EOSS-P with adolescents and measuring long-term outcomes such as cardiovascular disease incidence and all-cause mortality.

One review pooled data from 13 studies in paediatric populations and found a negative association between BMI and QOL (via PedsQL) ($r = –0.7$, $p = 0.008$) (37). The lack of association between BMI percentile and QOL in this study might be attributed to the narrow range of BMI percentiles in this sample of adolescents with high BMIs, as found in other studies with adolescents with severe obesity (38). Although only 7.4% of this sample of participants were categorized as overweight, they were required to have an additional weight-related comorbidity to qualify for this study. The results showed a negative association between BMI percentile and cardiorespiratory fitness. Conversely, BMI percentile was positively associated with upper and lower muscular strength. BMI is strongly associated with per cent body fat at the population level (4,7); however, it is a poor predictor of body fat at the individual level (4,7). Although BMI is a crude measure of body composition (7) and has received criticism in being an over-simplistic approach of determining paediatric obesity (3), it gives an indication of relative body size. A greater BMI would correspond to more fat mass and/or fat-free mass. Excess body fat has already been shown to be closely and negatively associated with cardiorespiratory fitness (25), while muscle mass (a major component of fat-free mass) has been shown to be positively associated with muscular strength (34,39). This can explain the positive association between BMI percentile and muscular strength and its negative association with cardiorespiratory fitness.

Many healthcare professionals are ill-equipped to address the needs of children and youth with obesity (40). EOSS-P and its 4Ms are intended to provide a more comprehensive individualized health risk assessment of a patient with obesity than the currently used anthropometric measurements (i.e. BMI). EOSS-P provides healthcare professionals with a structured framework containing a checklist of assessments on weight-related comorbidities and barriers to weight management that can help guide weight-management plans for their patients (1). A recent study investigated the perceived usefulness of the EOSS-P across various levels of care provided for paediatric patients with obesity (41). They found that EOSS-P was ranked as a very useful tool by 52.6% and somewhat useful by 31.6% from a sample of 57 referring healthcare professionals. Thus, the EOSS-P provides an improved and feasible methodology for stratifying health risk in paediatric obesity.

Obesity Canada refers to obesity as a ‘progressive chronic disease which is characterized by abnormal or excessive fat accumulation that may impair health’. Given this definition of obesity as a ‘progressive chronic disease’, EOSS-P would offer healthcare professionals a staging system to monitor the progression of obesity, analogous to staging of cancer. This study showed that participants with similar BMI or BMI percentile can present across the EOSS-P staging spectrum. Assessing obesity using BMI and EOSS-P would provide a more comprehensive health risk assessment and help distinguish individuals with similar BMIs at different stages in their obesity.

These findings indicate that as EOSS-P stages increase, QOL of a patient tends to decrease. Although it is reasonable to believe that improvements in EOSS-P stage would likely signify improvements in QOL, this issue warrants further investigation. These results also showed a lack of cross-sectional associations between EOSS-P, cardiorespiratory fitness and muscular strength. Because muscular strength and cardiorespiratory fitness are important physical health outcomes, one might consider measuring physical activity or fitness to improve assessment of obesity-related health risk in addition to EOSS-P in adolescents. Sedentary behaviour (i.e. any waking behaviour of low energy expenditure of less than 1.5 METS in a seated, reclined or lying position) and screen time have also been associated with health risks in children and youth (42,43). However, determining if a physical activity, fitness or sedentary behaviour assessment will improve obesity-related health risk remains to be investigated.

The American Heart Association in 2016 issued a scientific statement attesting to cardiorespiratory fitness being a vital sign that should be assessed routinely in clinical practice (23). It stated that the addition of cardiorespiratory fitness to other risk factors improves the classification of risk for adverse outcomes (23). In line with American Heart Association, the new US physical activity guidelines recommend that children and adolescents accumulate at least 60 min of moderate-to-vigorous activity daily, which includes mostly aerobic exercise, and muscle

and bone-strengthening activities (44). Considering the cost, time and requirement for additional personnel to conduct a fitness test, accelerometers or a physical activity and sedentary behaviour questionnaire might be more easily implemented or added to EOSS-P instead. However, it is important to acknowledge limitations with questionnaires, in that they may not provide the same quality of information as a fitness test, or an objective measure of physical activity and sedentary time would (i.e. accelerometry). Physical activity plays a pivotal role in the development of weight-related comorbidities (45), and it has already been suggested to include questions on physical activity in routine healthcare assessments (46).

The EOSS-P was designed as a risk stratification tool, with prognostic power. The mixed results seen in this study may be related to the fact that some of the health issues identified within the EOSS-P may not be negatively impacting health (cardiorespiratory fitness and QOL) at baseline but rather are thought to likely impact future health outcomes over time. Identifying this was not possible given the cross-sectional analysis of the surrogate markers of health at a single time point. For example, an adolescent with stage 2 or 3 health issues may not have a decline in cardiorespiratory fitness at baseline but may experience a decline in those markers over time.

There are several limitations of this study that should be mentioned. Firstly, the sample was mainly Caucasian (72%) and female (71%), which would affect the generalizability of the results to Canadian adolescents. Secondly, participants who were overweight required an additional comorbidity for inclusion, which may have biased a lower QOL in that group. Although it can be speculated that the qualifying comorbidities (e.g. high-normal fasting glucose, dyslipidaemia and family history of diabetes) would not tend to influence the QOL of an adolescent, future research is needed to examine this. Secondly, mental health assessments were derived from self-report questionnaires. The team of five experts from this research team came to a consensus on how to interpret a set of validated questionnaires for EOSS-P staging (Table 1). It is recommended that a clinical interview be performed by a healthcare professional for the EOSS-P mental health assessment as opposed to solely depending on self-report questionnaires to make a diagnosis. Thirdly, this is a secondary data analysis on variables that were not intended specifically for EOSS-P; thus, there were limited data on mechanical and social milieu categories. The limited data on these two categories may have caused underestimation of EOSS-P scores in some. Fourthly, to qualify for the HEARTY trial, participants had to adhere to a minimum of 12 of 16 exercise sessions (see HEARTY methods paper (28)). While this may not be a limitation to the overall HEARTY trial *per se*, this bias towards participants with higher adherence to exercise may affect the associations between EOSS-P and fitness outcomes. Lastly, this study was a cross-sectional design, which limits the causal inferences regarding associations.

Future studies should assess EOSS-P through a clinical evaluation of the 4Ms, as is intended for the EOSS-P. With this approach, researchers will have a better understanding of the EOSS-P because all EOSS-P variables would be measured. Future studies should also assess EOSS-P across various Tanner stages, as there are considerable physiological differences among people at 7different Tanner stages (30,31). Longitudinal health outcomes, such as the development of cardiovascular disease, all-cause mortality and EOSS stage in late adulthood, in larger samples are of interest to understand how EOSS-P can predict risk of obesity-related comorbidities over time.

Acknowledgements

The HEARTY trial was supported by grant MCT-71979 from the Canadian Institutes of Health Research. We gratefully acknowledge all HEARTY participants who dedicated their time to participate in this study. We acknowledge Dr. Simon Bacon for his thoughtful contributions to the EOSS-P algorithm and study design. G. A. K. was supported by the Faculty of Arts and Science Fellowship at Concordia University and les Fonds de Recherche du Québec – Santé (Master's Training Scholarship). A. S. A. was supported by les Fonds de Recherche du Québec – Santé (Chercheur Boursier Junior 1 at Concordia University).

Conflict of Interest Statement

The authors declare no conflicts of interest.

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